

## PATENT COOPERATION TREATY

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## INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P208201PCT HJO/jdo	FOR FURTHER ACTION See Form PCT/PEA/416	
International application No. PCT/NL2004/000421	International filing date (day/month/year) 14.06.2004	Priority date (day/month/year) 14.06.2003
International Patent Classification (IPC) or national classification and IPC F03D11/04, F03D7/04, F03B15/06		
Applicant ENERGIEONDERZOEK CENTRUM NEDERLAND (ECN)		
<p>1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 5 sheets, including this cover sheet.</p> <p>3. This report is also accompanied by ANNEXES, comprising:</p> <p>a. <input checked="" type="checkbox"/> <i>(sent to the applicant and to the International Bureau)</i> a total of 7 sheets, as follows:</p> <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).</li> <li><input type="checkbox"/> sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.</li> </ul> <p>b. <input type="checkbox"/> <i>(sent to the International Bureau only)</i> a total of (indicate type and number of electronic carrier(s)), containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).</p>		
<p>4. This report contains indications relating to the following items:</p> <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Box No. I Basis of the opinion</li> <li><input type="checkbox"/> Box No. II Priority</li> <li><input type="checkbox"/> Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</li> <li><input type="checkbox"/> Box No. IV Lack of unity of invention</li> <li><input checked="" type="checkbox"/> Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</li> <li><input type="checkbox"/> Box No. VI Certain documents cited</li> <li><input type="checkbox"/> Box No. VII Certain defects in the international application</li> <li><input type="checkbox"/> Box No. VIII Certain observations on the international application</li> </ul>		
Date of submission of the demand 14.04.2005	Date of completion of this report 29.08.2005	
Name and mailing address of the international preliminary examining authority:  European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer O'Shea, G Telephone No. +31 70 340-4424	



**INTERNATIONAL PRELIMINARY REPORT  
ON PATENTABILITY**

International application No.  
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**Box No. I Basis of the report**

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.
  - This report is based on translations from the original language into the following language, which is the language of a translation furnished for the purposes of:
    - international search (under Rules 12.3 and 23.1(b))
    - publication of the international application (under Rule 12.4)
    - international preliminary examination (under Rules 55.2 and/or 55.3)
2. With regard to the **elements\*** of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):

**Description, Pages**

1-12 as originally filed

**Claims, Numbers**

1-20 received on 14.04.2005 with letter of 14.04.2005

**Drawings, Sheets**

1/1 as originally filed

a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

- The amendments have resulted in the cancellation of:
  - the description, pages
  - the claims, Nos.
  - the drawings, sheets/figs
  - the sequence listing (*specify*):
  - any table(s) related to sequence listing (*specify*):
- This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
  - the description, pages
  - the claims, Nos.
  - the drawings, sheets/figs
  - the sequence listing (*specify*):
  - any table(s) related to sequence listing (*specify*):

\* If item 4 applies, some or all of these sheets may be marked "superseded."

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**Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

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**1. Statement**

Novelty (N)	Yes: Claims	1-20
	No: Claims	
Inventive step (IS)	Yes: Claims	1-20
	No: Claims	
Industrial applicability (IA)	Yes: Claims	1-20
	No: Claims	

**2. Citations and explanations (Rule 70.7):**

**see separate sheet**

**Re Item V**

**Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Reference is made to the following documents:  
D1: STEINBUCH M ET AL: "OPTIMAL CONTROL OF WIND POWER PLANTS" JOURNAL OF WIND ENGINEERING AND INDUSTRIAL AERODYNAMICS, XX, XX, vol. 27, 1988, pages 237-246, XP008023141  
D2: PARKIN P ; HOLM RICHARD ; MEDICI D: "The application of PIV to the wake of a wind turbine in yaw" 9 September 2001 (2001-09-09), DLR MITTEILUNG , XP008036399
2. Although the designation of claim 1 is for a turbine farm, the subject-matter consists of steps directed to a method of controlling a turbine farm. This apparent contradiction leads to a lack of clarity of the subject-matter of claim 1 (Article 6 PCT).

For the purposes of evaluating the subject-matter of present claim 1 for novelty and inventive step (Article 33(1)PCT), claim 1 has therefore been interpreted as *a method of controlling a turbine farm*.

- 2.1 The document D1 is regarded as being the closest prior art to the subject-matter of claim 1 and discloses (the references in parentheses applying to this document):

A method of controlling a turbine farm comprising at least a first turbine (see page 244, 2nd paragraph - page 245, 1st paragraph) and at least a second turbine by means of which energy can be extracted from a flowing fluid, whereby when the second turbine is on the lee side of the first turbine, under nominal power, the axial induction of the first turbine is lowered with respect to the second turbine.

The subject-matter of claim 1 differs from this known method in that the blade angles of the rotor of the first turbine are turned towards a feathering position.

The subject-matter of claim 1 with the above interpretation is therefore new (Article 33(2) PCT).

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(SEPARATE SHEET)**

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The problem to be solved by the present invention may be regarded as how to optimise the energy production of the turbine farm.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) for the following reasons:

By changing the blade pitch angle towards a feathered position on the first (or upstream) turbine, less flow energy is absorbed by the first turbine and hence the wake loss due to the presence of the first turbine is reduced, thereby allowing the second (or downstream) turbine to extract more energy from the flow. This leads to an optimisation of the power generated per unit area of the turbine farm, which in turn can lead to a more compact farm layout.

- 2.2 The same reasoning applies, mutatis mutandis, to the subject-matter of corresponding independent claims 14, 17 and 20, whose subject-matter therefore is also considered new and inventive.
- 2.3 The subject matter of claim 15 with the interpretation that it is directed to "Design software for a turbine farm capable of being controlled according to the method of claim 1.....etc", would similarly seem to satisfy the requirements of the PCT with regard to novelty and inventive step (Article 33(1)(29(3))).
- 2.4 Similarly, the subject matter of claim 16 with the interpretation that it is directed to "Control software for implementing the method according to claim 1, said control software being for a turbine farm ..... etc", would seem to satisfy the requirements of the PCT with regard to novelty and inventive step (Article 33(1)(29(3))).
- 2.5 Claims 2-13, 18 and 19 are dependent on claims 1 and 17 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

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## Claims

(100)

1. Turbine farm comprising at least a first turbine (1) and at least a second turbine (2) by means of which energy can be extracted from a flowing fluid (5), characterised in that when the second turbine (2) is on the lee side of the first turbine (1), under nominal power, the axial induction (a) of the first turbine (1) is lowered with respect to the second turbine (2), by turning the blade angles of the rotor of the first turbine (1) towards a feathering position to reduce turbulence mainly at the location of the at least second turbine.
2. ~~Turbine farm according to Claim 1, characterised in that the power of the farm as a whole does not fall.~~
32. Turbine farm according to one of the preceding claims, characterised in that the axial induction (a) of the first turbine (1) is reduced to 0.25 or less.
34. Turbine farm according to one of the preceding claims, characterised in that lowering of the axial induction (a) is further effected by reducing the speed of revolution and/or turning the blade angles of the rotor.
54. Turbine farm according to one of the preceding claims, characterised in that lowering of the axial induction (a) is effected by reducing the chord of the blades.

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56. Turbine farm according to Claim 54, characterised in that at least the first turbine has ~~rotor~~blades, each ~~rotor~~blade -having with a chord characteristic,  $\frac{Nc_r \lambda_r^2}{r}$ , of less than 3.75, where  $r$  is a radial distance that runs between  $0.5R$  and  $0.8R$ , where  $R$  is the radius of the rotor.

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76. Turbine farm according to one of the preceding claims, characterised in that a control system is provided, wherein this control system sets the axial induction (a) of at least one first turbine (1) in the farm as a function of the wind direction.

10 8. Turbine farm according to Claim 7, characterised in that the control system sets the axial induction of at least one turbine as a function of the turbulence in the wind.

15 7. Turbine farm according to Claim 6, characterised in that the control system sets the axial induction of the first turbine (1) on the basis of a measure for the turbulence determined at the second turbine (2) that is located essentially on the lee side of the first turbine (1).

20 108. Turbine farm according to Claims 76, 8 or 9 or 7, characterised in that the control system sets the axial induction (a) of at least one first turbine as a function of the distance to at least one second turbine located in the lee.

11. Turbine farm according to one of Claims 7, 8, 9 or 10, characterised in that this control system is able to set the axial induction of at least half of all wind turbines in said farm as a function of the wind direction.

12. Turbine farm according to one of Claims 7 to 11, characterised in that the control system sets the axial induction of at least one turbine on the basis of, *inter alia*, the distance to other turbines in the wake and/or on the basis of the number of turbines in the wake.

139. Turbine farm according to one of Claims 7 to 12 or 8, characterised in that the control system optimises the farm performance measured in terms of maximum yield and/or minimum loads by adjusting the axial inductions (a) of individual turbines.

1410. Turbine farm according to Claim 139, characterised in that the control system is self-learning.

1511. Turbine farm according to one of the above claims, wherein at least one wind speed at least one first turbine, essentially located on the windward side of the farm based on the dominant wind direction, differs in terms of axial induction from at least one second turbine, essentially located on the lee side of the farm, by on average more than 0.05.

16. ~~Turbine farm according to one of the above claims, characterised in that the turbine farm comprises at least 50 turbines and wherein the surface area occupied by the turbines is at least more than 3 % of the farm surface area.~~

5 17. ~~12. Turbine farm according to one of the above claims, characterised in that the axial force of the entire farm is reduced such that the power of another farm located in the lee is increased.~~

10 18. ~~13. Turbine farm according to one of the above claims, characterised in that the fluid is water and the turbines are water turbines that extract energy from a flow of water.~~

15 19. ~~14. Method for a turbine farm comprising at least one first turbine (1) and an at least second turbine (2) by means of which energy can be extracted from a flowing fluid (5), characterised by lowering the axial induction (a) of the first turbine (1) with respect to the second turbine (2) when the second turbine (2) is on the lee side of the first turbine (1), under nominal power, by turning the blade angles of the rotor of the first turbine (1) towards a feathering position, to reduce turbulence mainly at the location of the at least second turbine.~~

20 20. ~~15. Design software for a turbine farm comprising at least a first turbine (1) and at least a second turbine (2) by means of which energy can be extracted from a flowing fluid (5),~~

wherein the design software is able to calculate a favourable installation and a favourable method for the turbine farm,

characterised in that, the software is able to

- add guiding elements to the installation, and/or where turbines have a guiding function, and

when the second turbine (2) is on the lee side of the first turbine (1), under nominal power, the axial induction (a) of the first turbine (1) is lowered with respect to the second turbine (2) by turning the blade angles of the rotor of the first turbine (1) towards a feathering position, to reduce turbulence mainly at the location of the at least second turbine, to calculate the influence thereof on the turbine farm.

2416. Control software for a turbine farm comprising at least a first turbine (1) and at least a second turbine (2) by means of which energy can be extracted from a flowing fluid (5),

wherein the control software is able to determine at least one of meteorological parameters comprising wind speed and wind direction, temperature distribution and stability of the atmosphere

and to determine and set the power of the turbine farm as a function of at least one of parameters that can be set, comprising axial induction, speed of revolution, the rotor blade angle, angle of inclination, circulation scale and positions of the turbines,

characterised in that, the control software is able

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when the second turbine (2) is on the lee side of the first turbine (1), under nominal power, to lower the axial induction (a) of the first turbine (1) with respect to the second turbine (2) by turning the blade angles of the rotor of the first turbine (1) towards a feathering position to reduce turbulence mainly at the location of the at least second turbine by setting at least one of the parameters that can be set.

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22. Control software for a turbine farm according to Claim 21, characterised in that the software is able to find an optimum for the power of the turbine farm by setting the parameters that can be set.

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2317. Control system for a turbine farm comprising at least a first turbine (1) and at least a second turbine (2) by means of which energy can be extracted from a flowing fluid (5), characterised in that the control system is able, when the second turbine (2) is on the lee side of the first turbine (1), under nominal power, to lower the axial induction (a) of the first turbine (1) with respect to the second turbine (2) by turning the blade angles of the rotor of the first turbine (1) towards a feathering position to reduce turbulence mainly at the location of the at least second turbine.

2418. Control system according to Claim 2317, characterised in that the control system sets the axial induction of at least one first turbine in the farm as a function of the wind direction.

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25. Control system according to Claim 23 or 24, characterised in that said control system is able to set the axial induction of at least half of all wind turbines in said farm as a function of the wind direction.

5 2619. Control system according to one of Claims 23 to 2517 or 18, provided with control software according to Claim 2416.

27. Control system according to one of Claims 23 to 26 provided as central control system.

10 28. Control system according to one of Claims 23 to 26 provided as individual control system for the at least one first turbine.

2920. Turbine provided with control system according to Claim 2317.

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